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Analyzing Strategies for Eliminating Flame Blow-down Occurring in the Navy's 19F4 Fire Fighting Trainer

Glenn P. Forney
William D. Davis

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Building and Fire Research Laboratory
Gaithersburg, MD 20899

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Robert M. White, *Under Secretary for Technology*
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John W. Lyons, *Director*

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Analyzing Strategies For Eliminating Flame Blow-down Occurring in the Navy's 19F4 Fire Fighting Trainer

Glenn P. Forney* William D. Davis†

Abstract

This report documents a series of numerical experiments performed to analyze strategies for eliminating flame that is blown down below the elevated platform of the Navy's 19F4 fire fighting trainer. The first strategy involves the use of a fence in the way fences are used as tennis court wind breaks. The second strategy involves the use of fans to pressurize the space below the platform. Numerical simulations were performed for various fence heights, fence distances from the platform and fan volume flow rates. These tests confirmed that flame blow-down occurs when no action is taken to prevent it and predicted that blow-down will be reduced with the use of a fence and a fan.

1 Introduction

The Navy's 19F4 fire fighting trainer accurately simulates a real jet pool fire [1]. As illustrated in Figures 1 and 2, the trainer consists of an elevated platform with a central region consisting of steel grating below which are located propane burners. The release of propane is regulated so that under normal conditions (light or no wind) flame heights of 2.5 to 3 meters (8 to 10 feet) are attained. However, under moderate and heavy wind, the flames are blown into the space below the steel grating.

*Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899, U.S.A. (gpfrn@cf6.cfr.nist.gov).

†Building and Fire Research Laboratory, National Institute of Standards and Technology, Gaithersburg, MD 20899, U.S.A. (wdavis@cf6.cfr.nist.gov).

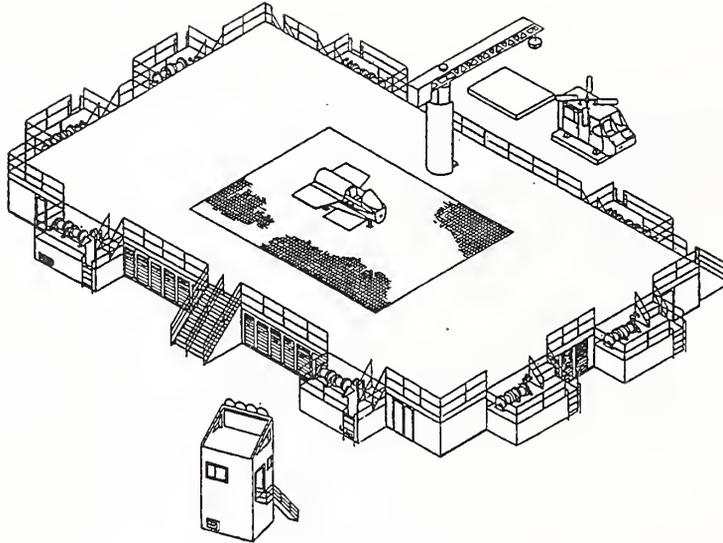


Figure 1: Perspective View of the 19F4 Trainer

The purpose of this report is to document a series of numerical experiments performed to analyze strategies for eliminating this blow-down. The first strategy involves the use of a fence in the way fences are used as tennis court wind breaks. The second strategy involves pressurizing the space below the grating using fans. Numerical simulations were performed for various fence heights, fence distances from the platform and fan flow rates. As will be discussed in more detail, these simulations confirmed that flame blow-down occurs when no action is taken to prevent it. Further numerical experiments predicted that the blow-down will be reduced with the use of a fence and a fan.

2 A Numerical Tool for Modeling Flame Blow-down

2.1 The Field Model

Release 2.3.2 of FLOW3D was used to perform the numerical simulations described in this report. This field model has been previously applied to model the fire at the King's Cross underground station [2]. Of interest here is that

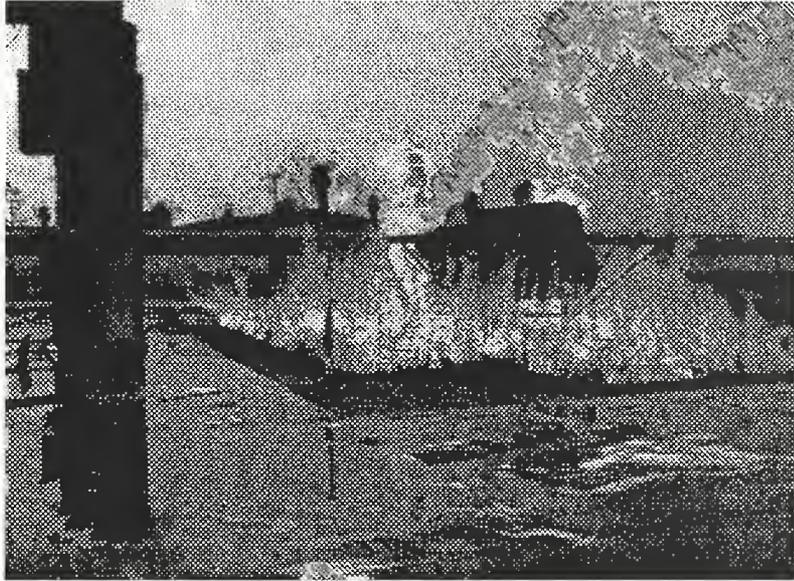


Figure 2: Flames at the 19F4 Trainer Under No-Wind Conditions

it predicted unexpected flow patterns¹ which were subsequently verified with 1/3 scale fire experiments[3]. The field model was also successfully applied to two well instrumented full scale room experiments [4].

This model has been developed over a period of roughly a decade at Harwell Laboratories. The field model solves the three dimensional form of the equations for conservation of mass, momentum, and energy and the $k-\epsilon$ model is used to model turbulence. The required physical parameters for these equations include the fluid density, pressure, specific heat at constant pressure, acceleration of gravity, thermal conductivity and molecular viscosity.

The physical setups for the numerical experiments were as follows. It was assumed that the fluid was air and that it was fully compressible. Turbulence was modeled using the $k-\epsilon$ model and included the default treatment of the boundary layer near the ground, fence and trainer platform. The platform and the fence were assumed to be adiabatic. Radiation effects were not included in the calculation.

A rectangular, non-uniform grid was used to model each experiment. All terms in the equations except for the advection terms were discretized in space using second-order centered differencing. A number of discretization schemes

¹The field model predicted flow along the base of the escalator rather than vertical flow towards the ceiling

were available for modeling the advection terms. For this work, the upwind differencing scheme was used. The equations were advanced in time using a fully implicit backward difference procedure.

2.2 Visualizing the Results

The field modeling software package, FLOW3D, includes three output graphics programs used to visualize the simulation results: OUTPROC, TRAN, and SURF3D. Each program was used during the course of the work described in this report, though only the results from OUTPROC are presented here.

OUTPROC, produces contour and velocity vector plots. A velocity vector plot consists of a sequence of arrows where the length and direction of the arrow indicates the speed and direction of the wind flow. The color of the arrow indicates the temperature of the flow. However, the velocity vector plots are only reproduced in black and white for this report. The contour plots indicate lines (the contour) of equal temperature. The files used by OUTPROC to produce the plots in this report are listed in Appendices B and C.

TRAN, provides a two dimensional animation of the time evolution of a designated variable on the grid. Each node point on the grid is given a color representing the magnitude of the variable at that node. The program displays the variable values at each timestep.

SURF3D, provides a three dimensional visualization of the surface boundaries (hence the name SURF3D) at one particular time for the grid used in the calculation. Several variables such as temperature or pressure may be displayed on the grid boundaries using a color representation for the variable's magnitude. The grid may be expanded, rotated, or translated and the user has the option to move within the grid boundaries to observe the internal structure of the grid surfaces. SURF3D also makes it easier to verify that boundaries, the fence and the platform for example, are set up correctly.

3 Numerical Experiments

Several two and three dimensional numerical simulations were performed as summarized in Table 1. The bulk of the work was done using two dimensions due to the long computer run times (24 hours for 3-d, 2.5 hours for 2-d) required for the 3-d simulations. Several 3-d runs were made however in order to verify the results of the 2-d simulations.

Table 1: Summary of 19F4 Numerical Test Runs

Case	Description
A	The Two dimensional “base” case; a wind profile with no fence or fan
B	Two dimensional simulation with steel “skirts” surrounding the propane burners.
B.1	Two dimensional simulation with a fence used to break the wind. The fence goes all the way to the ground
C	Two dimensional simulation with a fence used to break the wind.
D	Two dimensional simulation with a fence and a fan with a low volume delivery rate.
E	Two dimensional simulation with a fence and a fan with a high volume delivery rate.
E-1	Two dimensional simulation with a fan and no fence. The leeward side of the platform is totally blocked.
E-2	Two dimensional simulation with a fan. The trainer is enclosed in a building except for an opening above the burners.
F	Three dimensional simulation without a fence
G	Three dimensional simulation with a fence

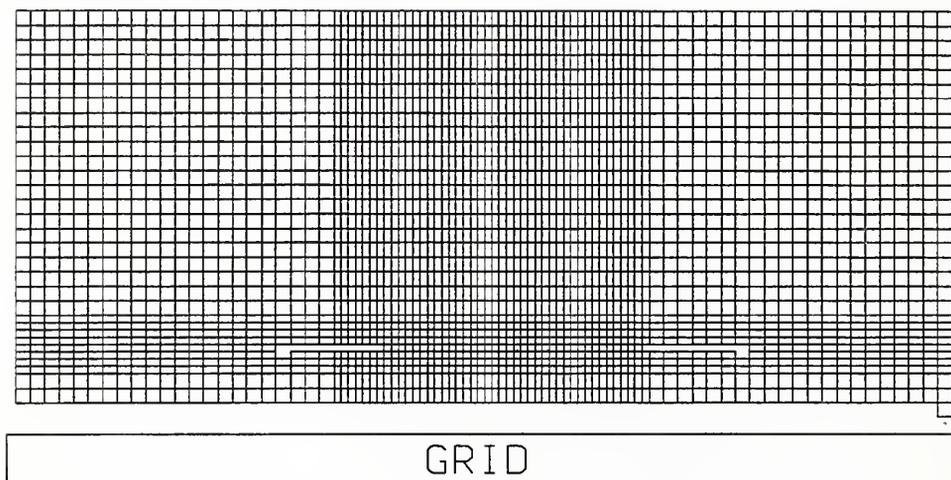


Figure 3: Gridding Used for Two Dimensional 19F4 Numerical Simulations

3.1 Two Dimensional Simulations

3.1.1 Setting Up the Two Dimensional Numerical Calculations

This section will provide some details of how the 19F4 trainer was modeled in 2 dimensions using the field model. Four components of the trainer model are the wind, the fire, the fence and the fan. Another important aspect of the model is the gridding; how the region around the trainer was discretized into a collection of control volumes.

Setting Up the Grid Used by the Field Model There is a tradeoff between the size or coarsness of the grid and the computer time required to run the resulting simulation. The finer the grid the more precise the simulation but at an increase in run time cost. The grid used for case A is shown in Figure 3. A schematic of the numerical setup is illustrated in Figure 4. Cases B through E use the same grid except for blockages defined to model the steel curtain in Case B and a fence in cases C, D and E. A grid with $87 \times 32 \times 3$ cells was used to model the trainer and the fence. The cells near the fire were of size $0.3 \text{ m} \times 0.3 \text{ m}$ (1-foot \times 1-foot). It was felt that this was the most important region in the simulation. The run-file used by the field model for Case A is given in Appendix A.

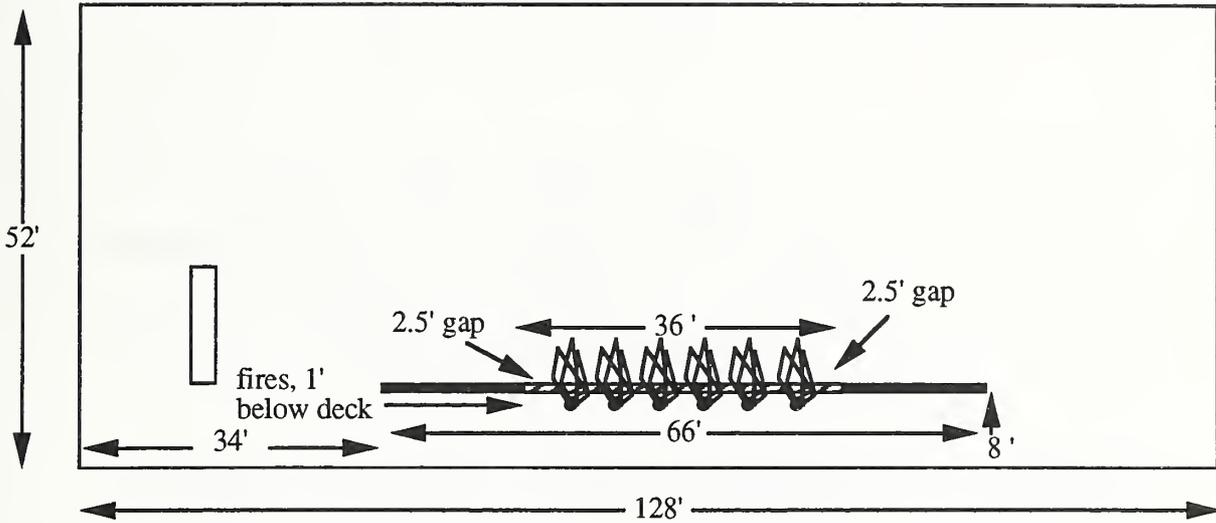


Figure 4: Schematic Diagram of the 19F4 Trainer Numerical Setup

Modeling the Wind The wind was assumed to be steady. The variation of wind velocity with height was modeled using a standard power law [5, 6],

$$v(z) = v_{ref} \left(\frac{z}{z_{ref}} \right)^{.14} \quad (1)$$

where $v(z)$ is the velocity of the wind at height z and v_{ref} is the velocity at a reference height z_{ref} . The reference velocity was chosen to be 7.62 m/s (15 knots) at a reference elevation of 5.5 m² (18 feet).

Modeling the Fire The fire was modeled as an “electric” heater. Approximately 10⁶ W/cell was released in grid cells located below the platform. Referring to Figure 4, the heat was released in two rows of cells located below the platform. These cells correspond to the location of the propane burners. This was accomplished by the Fortran subroutine USRSRC which is listed in Appendix B.

The results described for the 2-d simulations in this report are at ten seconds into the burn. The heat source simulating the burner was turned on at time zero. Based on numerical calculations for ten seconds into the burn, the simulations had reached approximate steady state.

²³ m (10 feet) above the platform which in turn is 2.5 m (8 feet) above the ground

Modeling the Fence and Training Platform The fence was modeled using the INLET boundary condition capability provided by the field model. The field model allows a quantity (velocity of air in this case) of a material absorbed or emitted at a boundary to be specified by a user. The permeability of the fence was modeled by allowing a portion of the wind velocity (.5 m/s) to pass through. Figure 4 illustrates the size and location of the fence in relation to the training platform. This configuration was used for the numerical simulations reported in this report. The fence was 6.1 m (20 feet) tall with the bottom 2.4 m (8 feet) open. The training platform was modeled by specifying one row of cells 2.4 m (8 feet) off the ground as solid blockages. The distance between the platform and the fence was modeled as 5.5 m (18 feet).

Modeling the Fan The fan was modeled by prescribing the volume flow rate at the boundary below the 19F4 trainer platform. The velocity of the flow was set so that the volume flow rate was $15 \text{ m}^3/\text{s}$ (32,000 cfm) for Case D and $60 \text{ m}^3/\text{s}$ (130,000 cfm) for Case E. The cross-sectional area for the flow inlet was approximately 229 m^2 so a vertical velocity of .067 m/s for Case D and .269 m/s for Case E was specified in the field model input file.

3.1.2 Qualitative Model Verification

A qualitative assessment of the field model for modeling flame blow-down was made by comparing known trainer scenarios with corresponding simulation results. A quantitative comparison was not possible due to the lack of wind velocity and temperature measurements at various locations around the 19F4 trainer.

The field model predicts the presence of flame blow-down under windy conditions. Figure 5 shows the velocity field of the wind and the temperature contours for this case. The temperature contours in Figures 5, 7, \dots , 10 range from 350 K to 650 K in increments of 50 K. Note the slight dipping of the arrows in the central region where the fire is located. Also note that the arrows above the deck are parallel to the deck.

The field model can be compared to a second physical scenario involving the trainer. A set of steel "skirts" were attached to the perimeter in an attempt to reduce the flame blow-down. It was observed that the effect was quite the opposite. The flames were driven below the deck more forcefully than before. With the benefit of hindsight and the aid of the field model, it was determined that the steel skirt in the presence of the wind formed a low pressure zone on the leeward side (where the propane burners were located). This low pressure zone caused the flames to blow-down or to be sucked into this region. Both

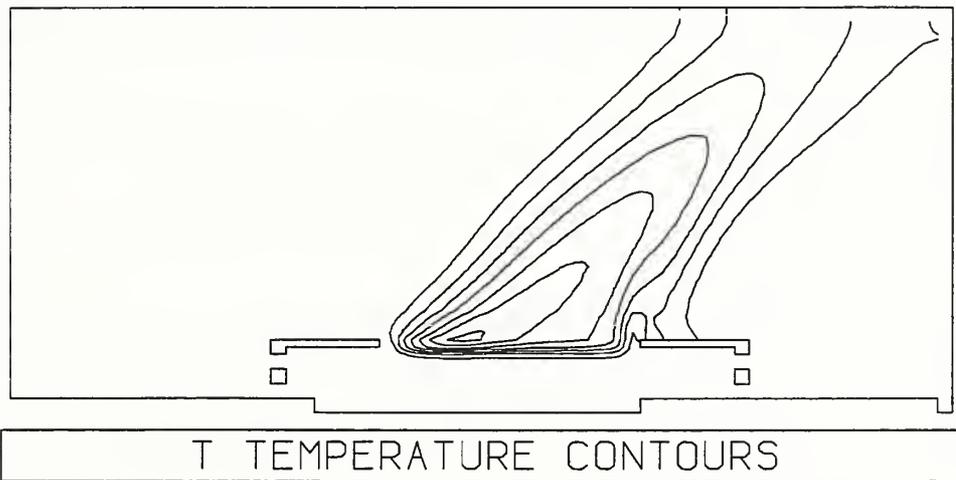
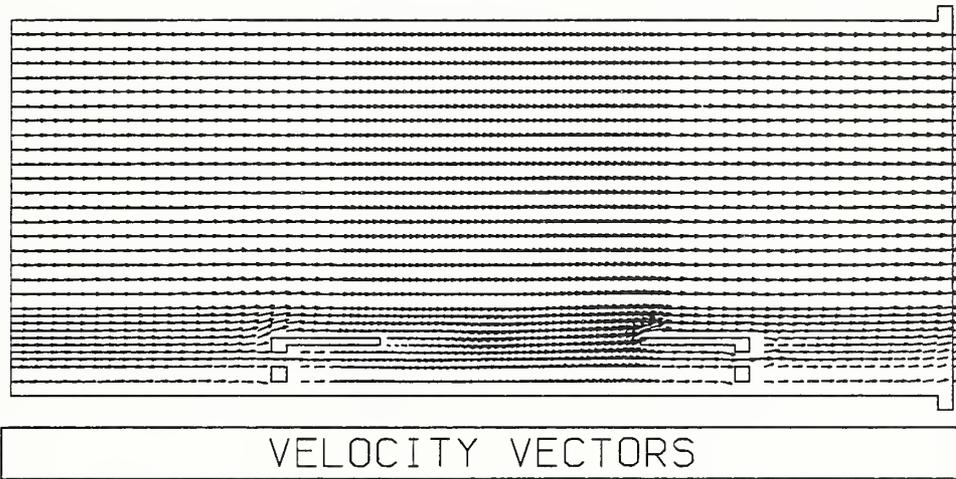


Figure 5: Velocity Vectors and Temperature Contours for Case A (wind, no fence, no fan)

plots in Figure 6 illustrate this. Note that in Figure 6 the presence of downward pointing arrows more extreme than in Figure 5. Also the central region of hot gas as illustrated in the contour plot in Figure 6 is farther below the deck than the corresponding region in Figure 5.

With the success of these two simulations, it was felt that the field model could analyze strategies for reducing the flame blow-down.

3.1.3 Two Dimensional Simulation Results

Four scenarios for reducing flame blow-down are discussed. The first two cases (cases B.1 and C) involve the presence of a permeable fence. This could consist of a tall fence covered with slats or some type of mesh screening. The fence in Case B.1 extends all the way to the ground while the fence in Case C is open at the bottom 2.4 m (8 feet). The third and fourth cases (cases D and E) involve the use of a fan in conjunction with the same fence as used in Case C.

Figure 7 illustrates the importance of having a fence that is open near the ground. The solid blockage in the fence near the ground forces all the air to go over the top of the fence resulting in a low pressure zone. As a consequence, the flame is drawn towards the fence. Figure 8 illustrates the simulation results for Case C (fence without a fan). Note in Figure 8 the absence of downward pointing arrows in the region where the propane burners are located. Also note the presence of a circulation pattern slightly above the platform on the left side of the trainer. If this pattern were above the fire which could occur if the fence is too close to the platform then flame blow-down would occur. The central region of hot flame in the contour plot in Figure 8 is higher than the corresponding region in Figures 5 or 6.

Figure 9 illustrates the results of Case D; a fence and low fan flow. The central temperature contour in Figure 9 is farther above the deck than the corresponding contour in Figure 8.

Figure 10 illustrates the results for Case E; a fence and high fan flow. The elevation of temperature contour in Figure 10 is even farther above the deck than in Figure 9.

3.1.4 Additional Two Dimensional Simulations

Two additional geometries were investigated as possible solutions to the blow-down problem. The first geometry excluded the fence but kept the fan and enclosed the back area beneath the deck at the downwind end of the deck. For this case, the fan flow rate was $15 \text{ m}^3/\text{s}$ (32,000 cfm). The temperature

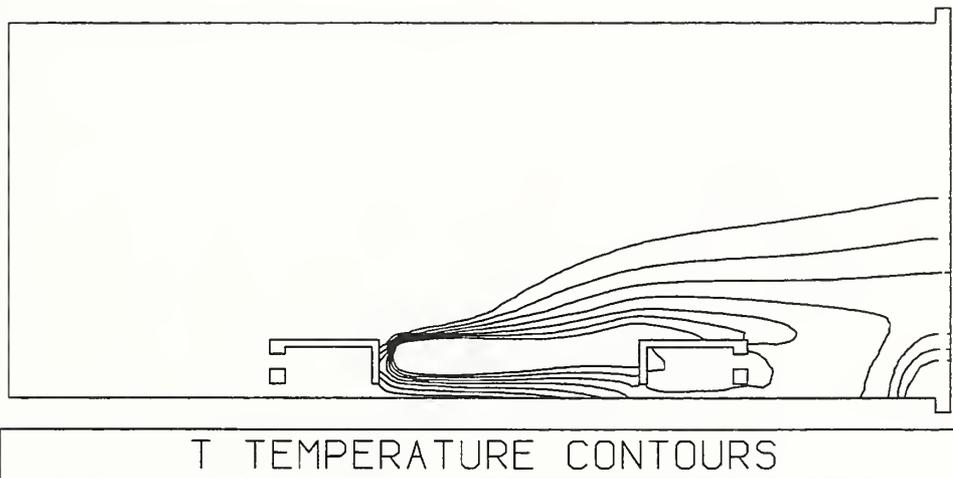
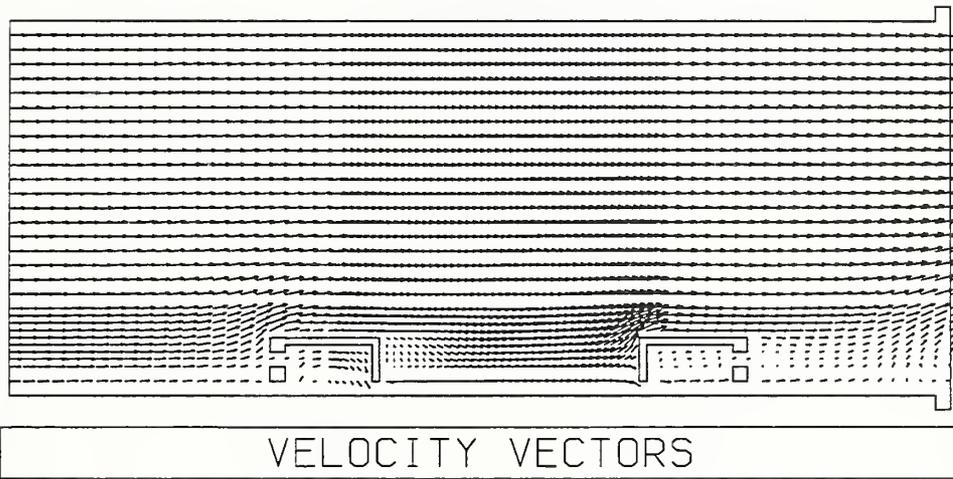


Figure 6: Velocity Vectors and Temperature Contours for Case B (wind, no fence, steel skirts, no fan)

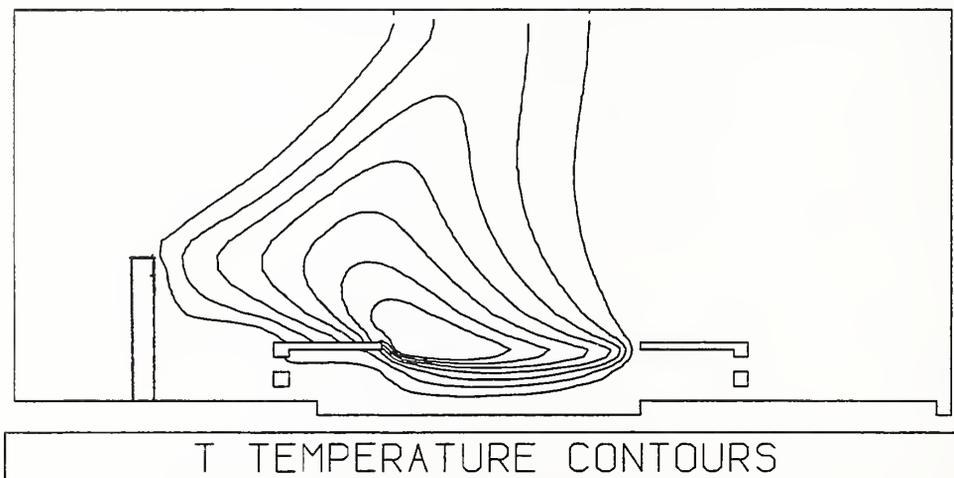
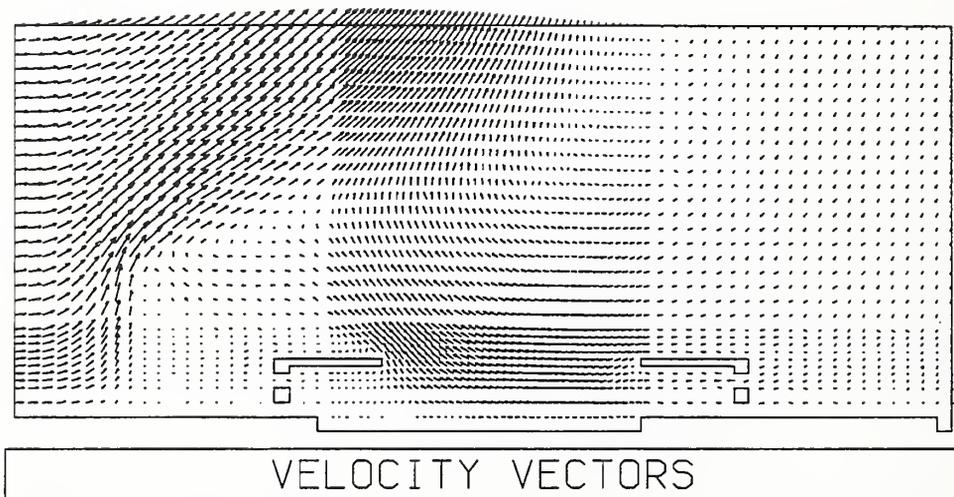
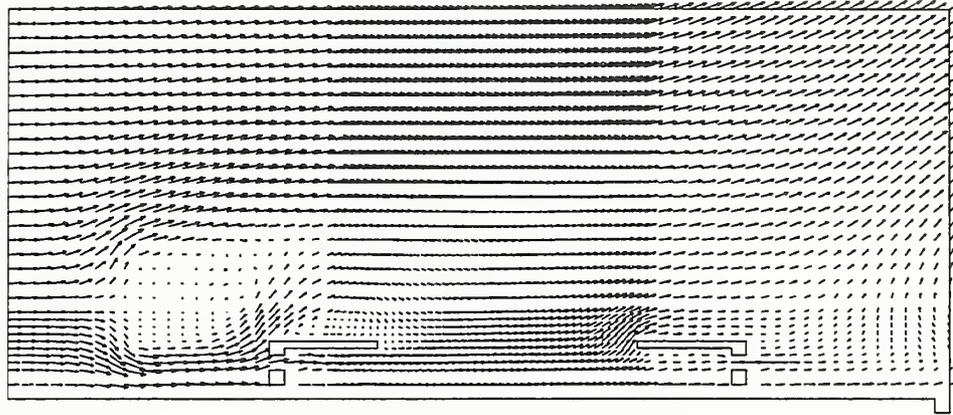
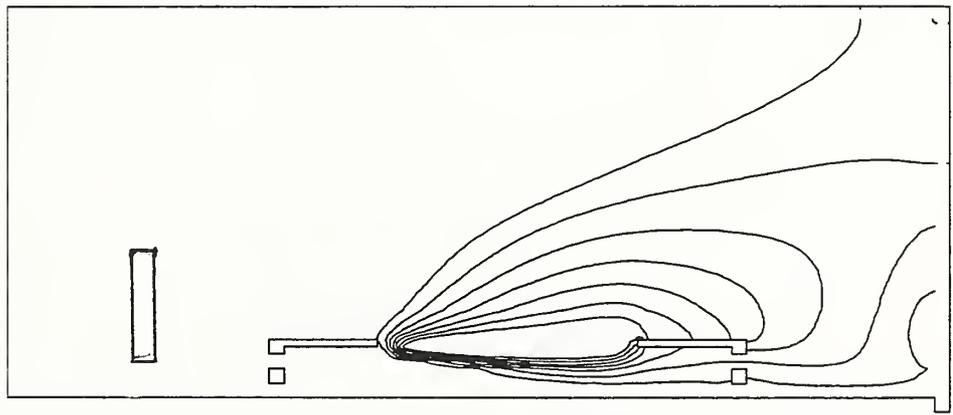


Figure 7: Velocity Vectors and Temperature Contours for Case B.1 (wind, fence blocked near ground, no fan)



VELOCITY VECTORS



T TEMPERATURE CONTOURS

Figure 8: Velocity Vectors and Temperature Contours for Case C (wind, fence open near ground, no fan)

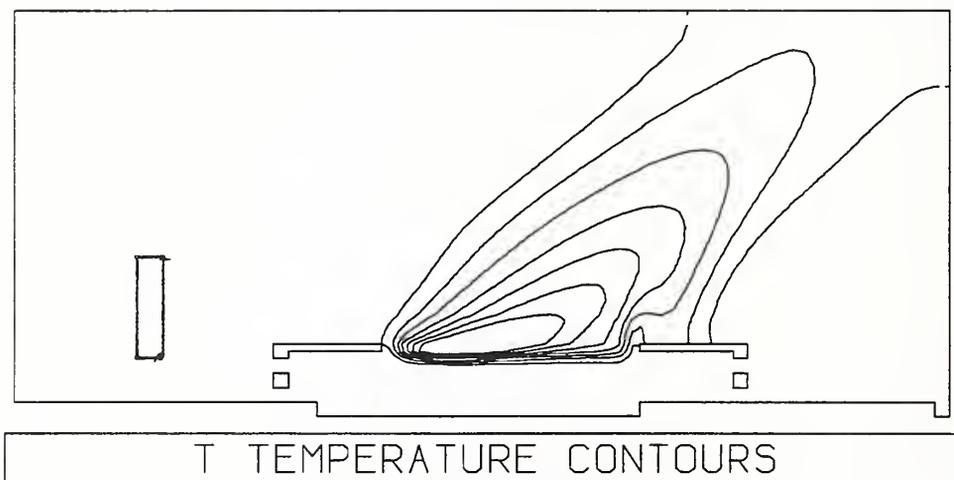
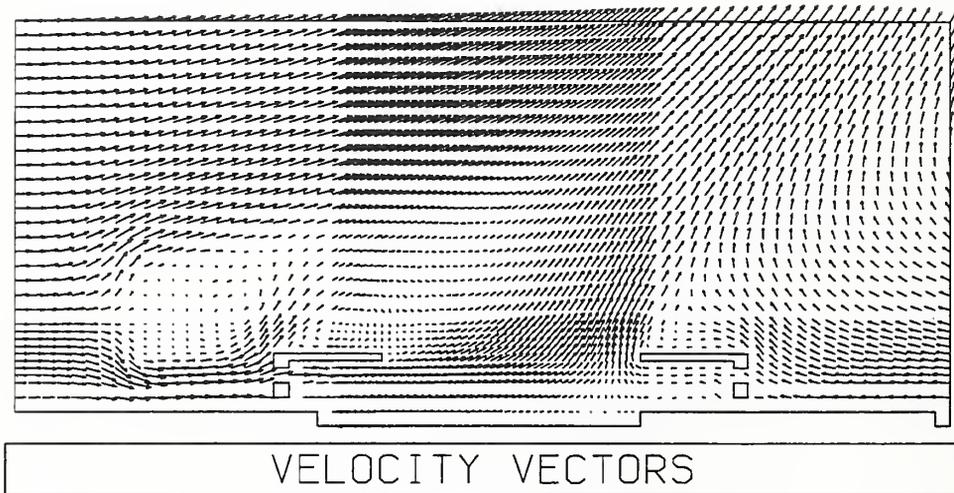


Figure 9: Velocity Vectors and Temperature Contours for Case D (wind, fence open near ground, low fan flow)

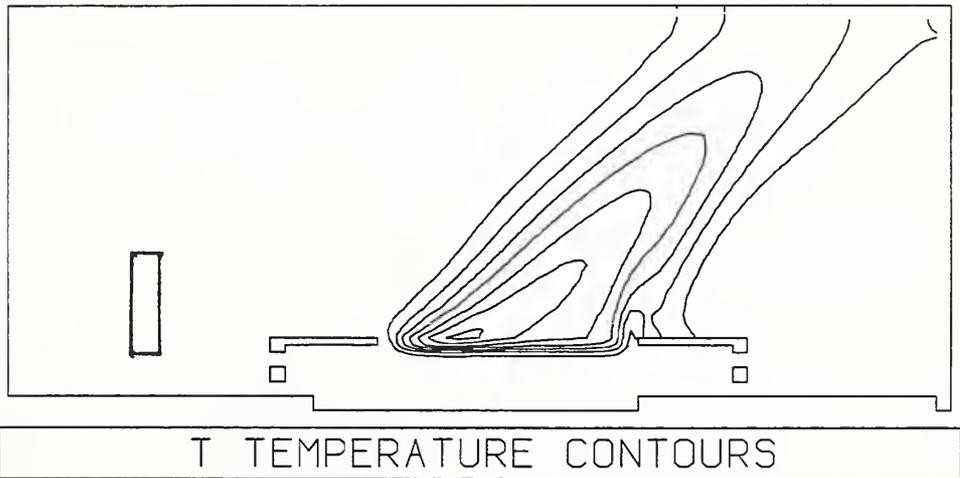
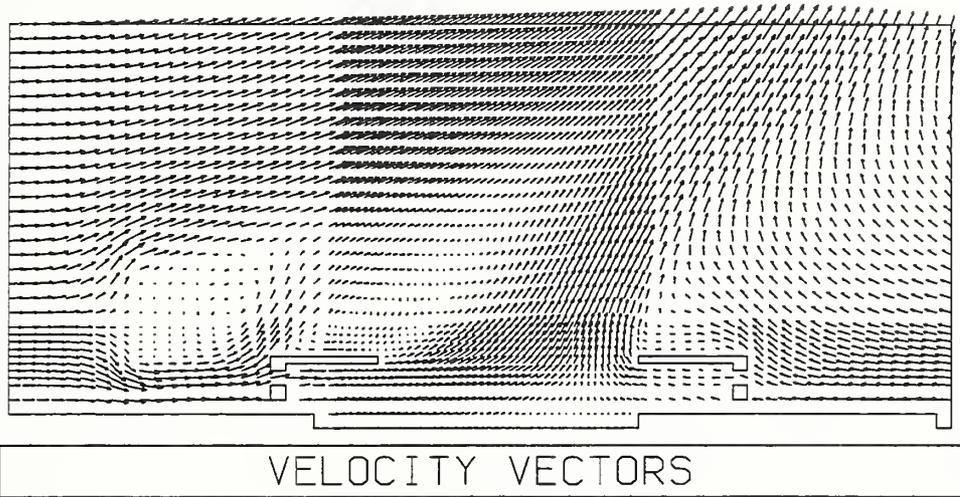


Figure 10: Velocity Vectors and Temperature Contours for Case E (wind, fence open near ground, high fan flow)

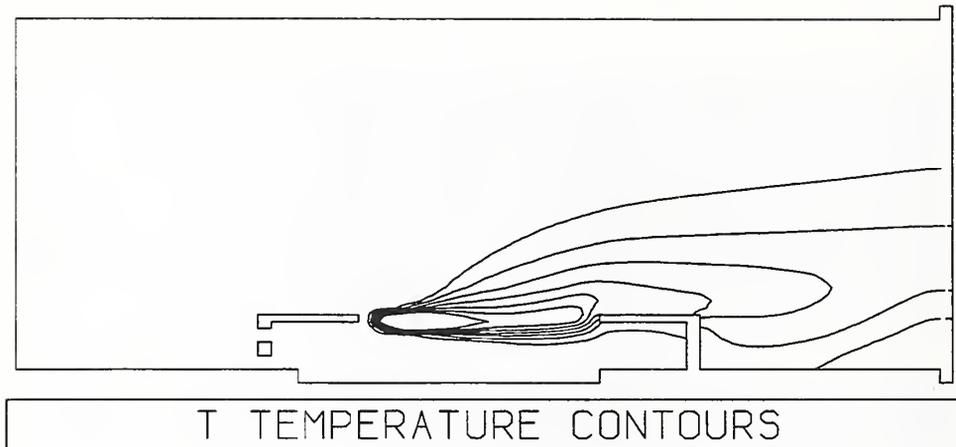


Figure 11: Temperature Contours for Case E-1 (wind, no fence, enclosed platform (on back side), low fan flow)

profile for this simulation is given in Figure 11. The temperature profiles range from 350 K to 650 K in increments of 50 K. As can be seen, as long as the wind is blowing straight into the enclosed deck space, this geometry can be reasonably effective in preventing hot gas from flowing beneath the deck. For wind conditions at an angle to the back of the deck, this geometry will probably not produce the necessary pressure gradient to prevent hot gas from flowing beneath the deck.

The second geometry consisted of enclosing the deck except for an opening directly over the open fire area. The ceiling of this enclosure was located 5.2 m (17 feet) above the deck surface. The temperature profile for this simulation is given in Figure 12. Enclosing the back portion of the deck and putting a partial roof on the deck traps the high temperature gas inside the enclosure and forces some of this gas underneath the deck. Based on this simulation and other simulations with enclosures downwind of the burners, geometry which constricts the flow downstream of the fire should be avoided.

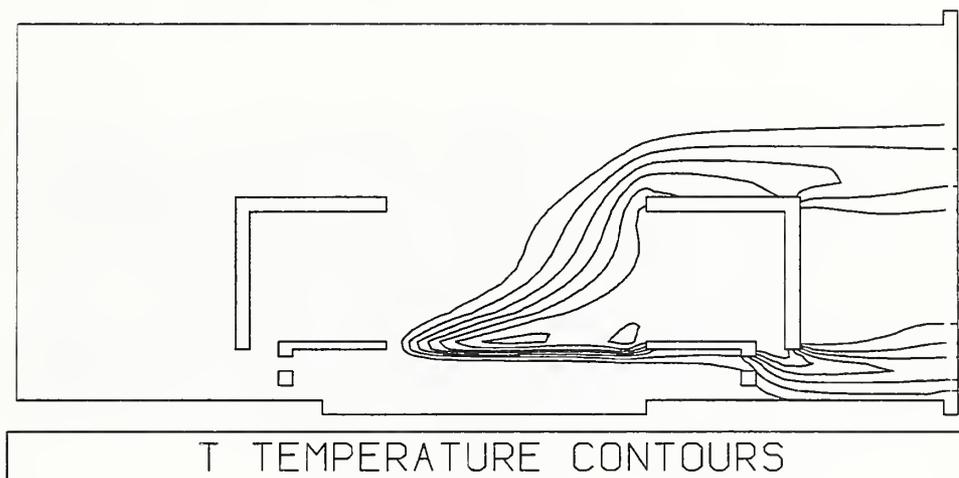


Figure 12: Temperature Contours for Case E-2 (wind, no fence, enclosed trainer (except for area above burners), low fan flow)

3.2 Three Dimensional Simulations

3.2.1 Setting Up the Three Dimensional Simulations

The effect of wind blowing at an angle to the fence was studied using a three dimensional simulation of the 19F4 trainer. The problem was set up in the following manner. A grid of $45 \times 32 \times 38$ was used to model the trainer and fence. The grid size was kept constant at 1.2 m (4 feet) in both horizontal (X and Z) directions. Vertically (Y), the grid size was 0.6 m (2 feet) for the first 1.2 m (4 feet) above the ground, 0.3 m (1 foot) for the next 2.4 m (8 feet), and 0.6 m (2 feet) for the next 12.2 m (40 feet). The boundary conditions consisted of inlets, which supplied the wind, on two adjacent sides of the grid and outlets on the other two sides and top of the grid. The bottom of the calculational grid (the ground) was impervious to flow. The fence surrounded two sides of the trainer, began at deck level, and extended to a height of 4.6 m (15 feet) above the deck. The fence was located 4.9 m (16 feet) from the edge of the deck in both horizontal directions and had a thickness of one grid or 1.2 m (4 feet). The deck had a thickness of 3 m (1 foot). The propane burners were simulated using a uniform heat release of 13600 W/m^2 (146000 W/ft^2) over an area of $13.4 \times 8.5 \text{ m}$ ($44 \times 28 \text{ feet}$) centered in an opening of 52×36 grids

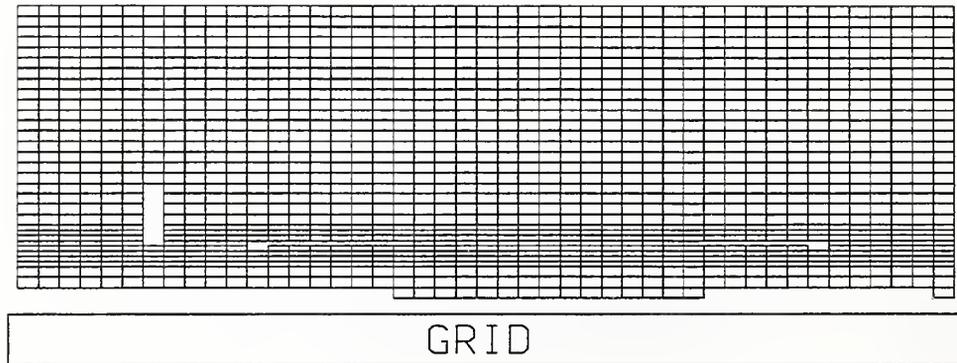


Figure 13: Grid for Case F (Three dimensional simulation with a Fence) in the XY Plane

at a height of .6 m (2 feet) below the deck surface. Underneath the opening at ground level, the flow rate of the pressurization fan was $15 \text{ m}^3/\text{s}$ (32,000 cfm). This was simulated using a vertical forced flow of velocity 0.06725 m/s covering an area of 20.1×13.4 (66×44 feet) and centered on the opening in the trainer platform. Obstructions beneath the deck were simulated using solid blockages, each 0.3 m (1 foot) thick, located on the perimeter of the deck at 0.3 m (1 foot) below the deck and at 1.2 m (4 feet) below the deck. Figure 13 shows the grid in the XY plane with a fence. As seen in this Figure, the gridding used is coarser and does not encompass as large an area as the grid used for the 2-d simulations, illustrated in Figure 3.

The steady wind profile as a function of height was identical to the two dimensional calculations. The wind direction was changed such that the wind blew at an angle of forty-five degrees with respect to either of the fence surfaces.

The heat source simulating the burner was turned on at time zero. The results described for the 3-d simulations in this report are at five seconds into the burn. Based on numerical calculations for ten seconds into the burn, the simulation had reached an approximate steady state value by five seconds.

3.2.2 Three Dimensional Simulation Results

The 19F4 trainer was simulated in three dimensions both with fences and fans and without fences and fans for a single wind speed and direction. The results of the simulations are presented in Figures 14 through 17 as two dimensional slices showing temperature contours and velocity vectors in the XY and YZ planes. The temperature contours start at 350 K and increment at 50 K intervals reaching a maximum value of 650 K. The slices were positioned to be on the downwind side of the burners but still in the opening which would permit the fire location to be displayed on the slice. Looking first at the XY plane, the results of the simulation with the fence and fan is presented in Figure 14 while Figure 15 provides the results of the same simulation without the fence and fan. For the YZ plane, Figure 16 gives the results with the fence and fan and Figure 17 gives the results without the fence and fan. In both planes, the results clearly show that the combination of the fence and fans provided sufficient lift of the air flow to avoid high temperature air from flowing beneath the deck. The flow simulation for the three dimensional calculation does not have the detail of the two dimensional calculations owing to the necessity of choosing a coarser grid to do the simulation. In both the two and three dimensional calculations, the combination of the fence and fans should prevent flame blow-down with the unwanted flow of hot gas under the trainer deck.

4 Summary and Conclusions

A field model was used to analyze and evaluate strategies for eliminating flame blow-down. Several simulation runs were shown to agree qualitatively with known physical scenarios. The model then predicted that flame blow-down will be eliminated when a fence is used to block the wind and a fan is used to pressurize the space below. Three dimensional runs were made that showed that the direction of the wind was not a factor. These runs also verified that the 2-d and 3-d results were consistent. Many 2-d runs were made varying the location of the fence. The favorable effect of the fence was shown to be fairly insensitive to its distance from the platform over a range of 4.5 m to 7.5 m (15 to 25 feet).

The fence and fans were installed at the Treasure Island 19F4 training facility after these simulations were performed and worked as expected.

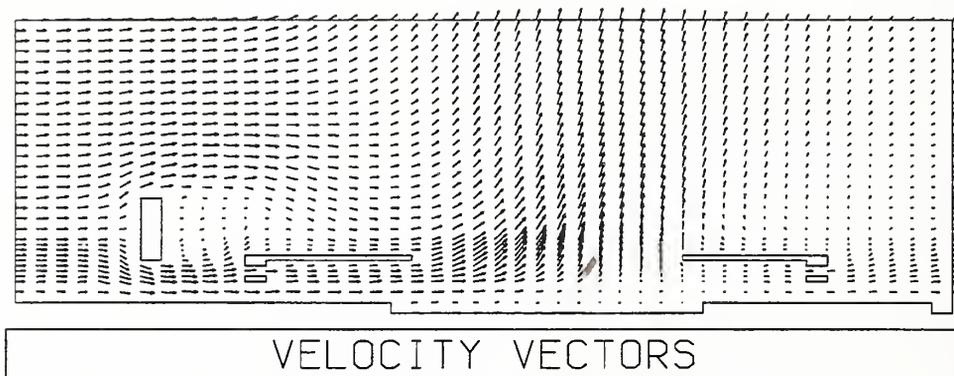
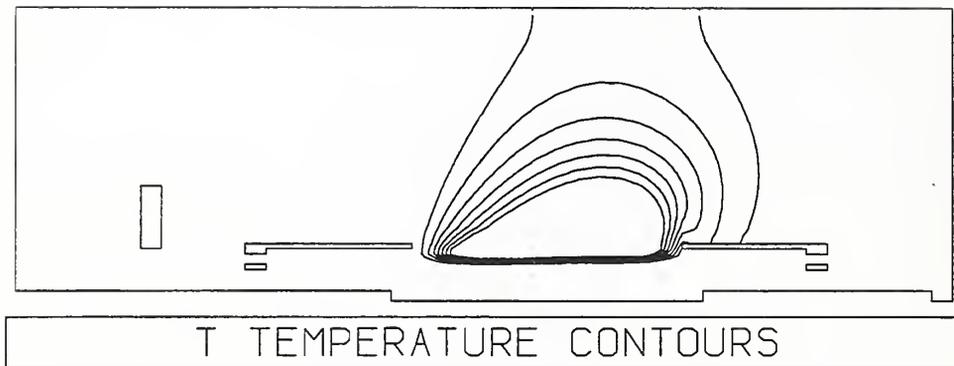


Figure 14: Three Dimensional Results in the XY Plane for a Simulation with a Fence and Fan

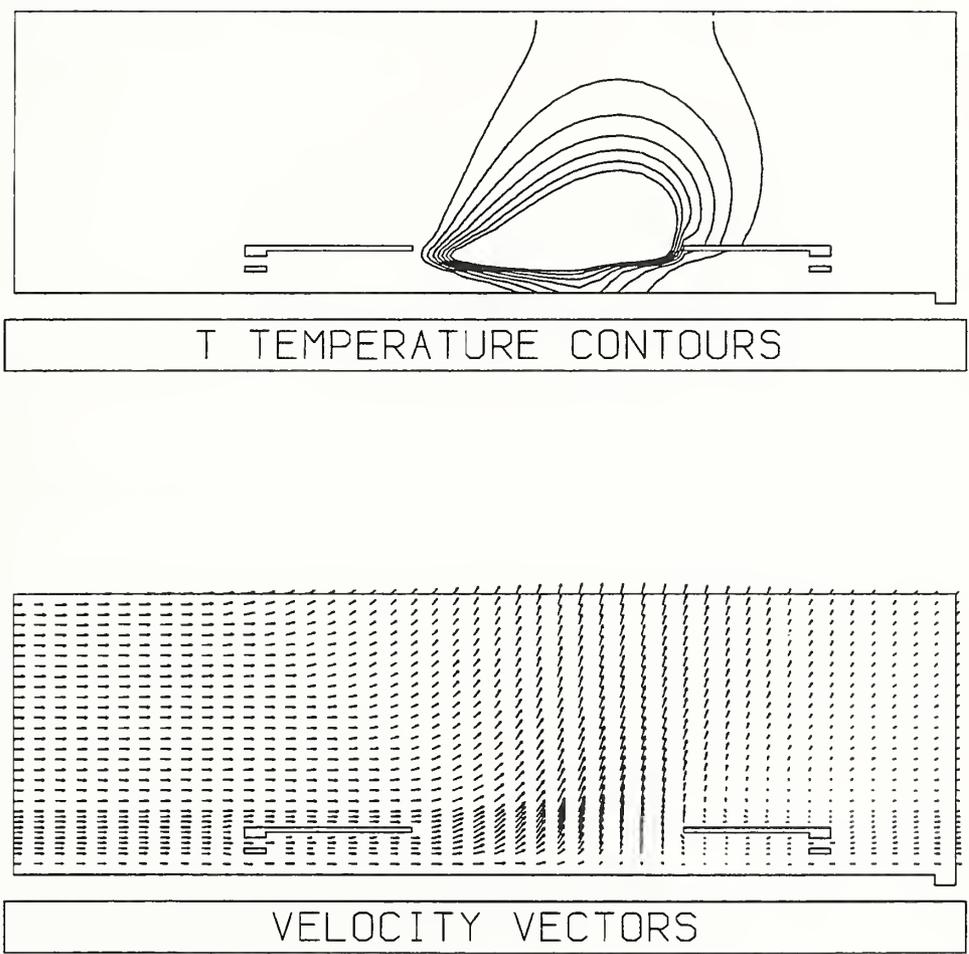


Figure 15: Three Dimensional Results in the XY Plane for a Simulation without a Fence and Fan

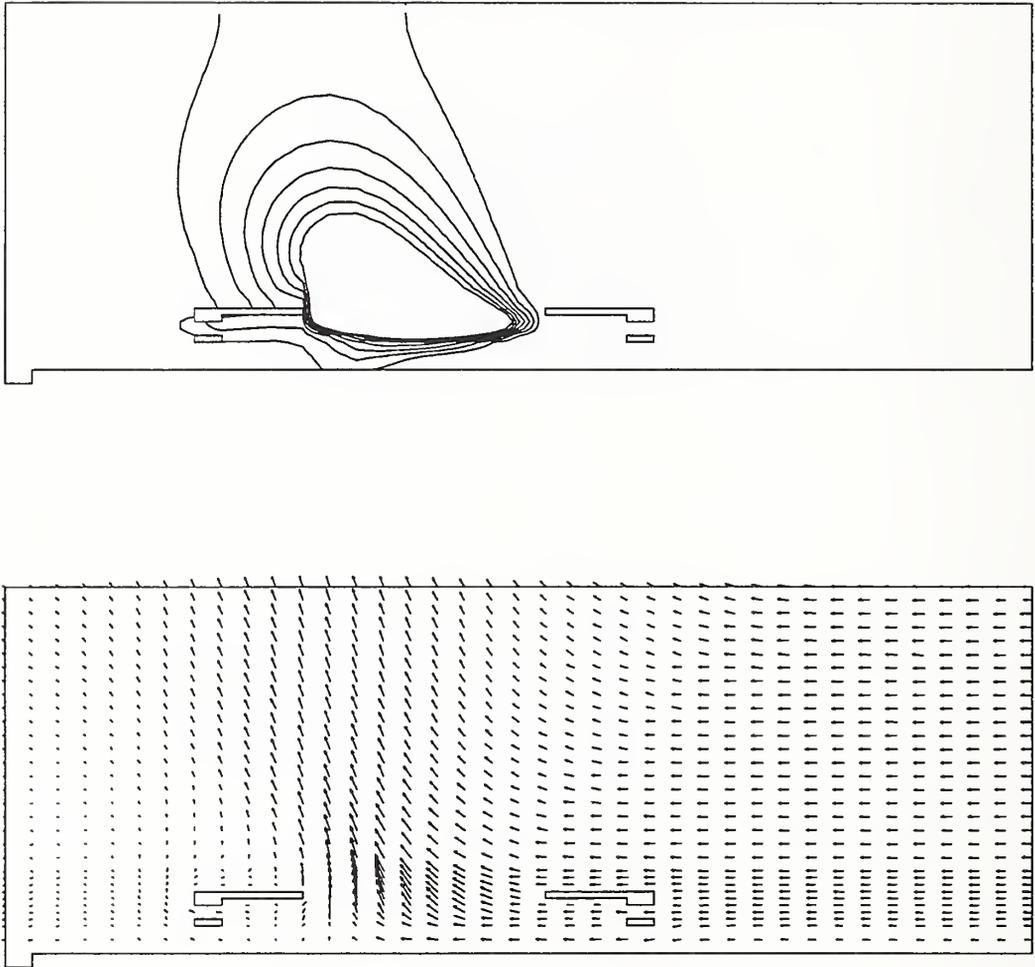


Figure 16: Three Dimensional Results in the YZ Plane for a Simulation with a Fence and Fan

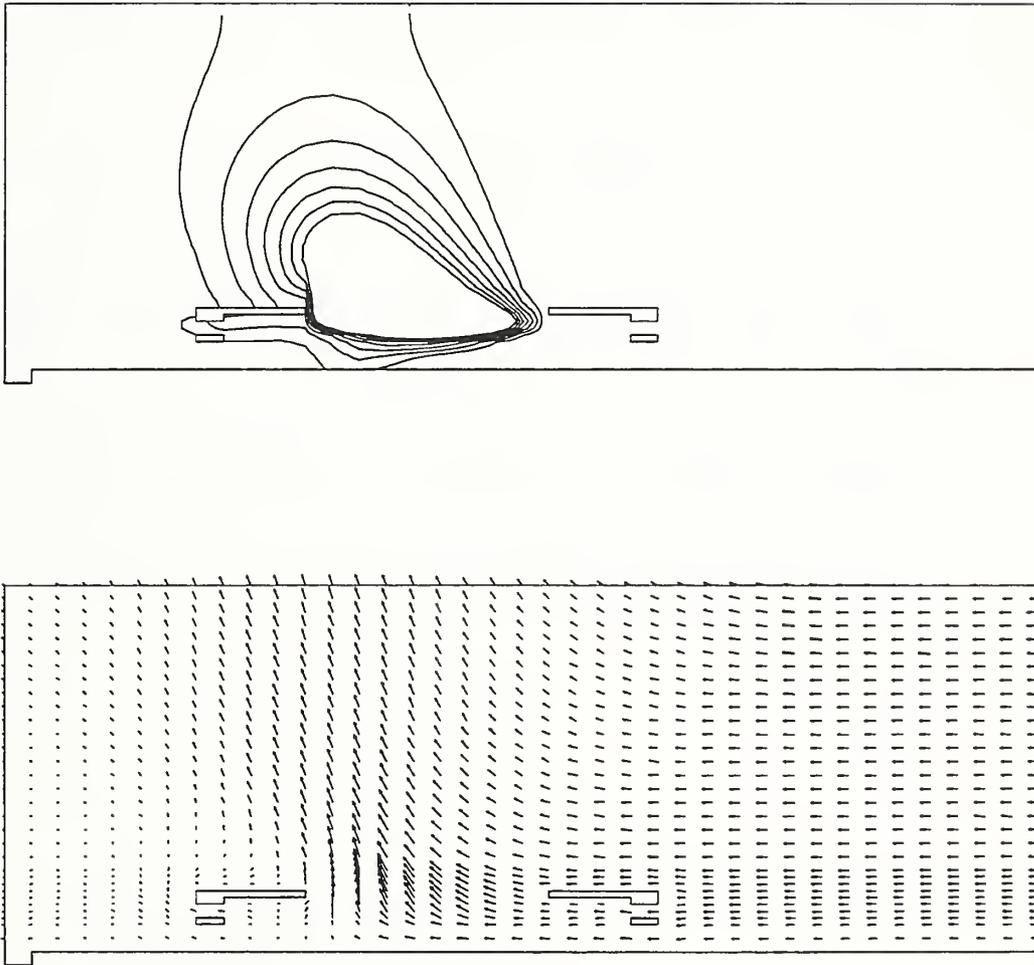


Figure 17: Three Dimensional Results in the YZ Plane for a Simulation without a Fence and Fan

References

- [1] Robert Levine. Measurements on the 19f4 fire fighter trainer. letter report, 1991.
- [2] S. Simcox, N. S. Wilkes, and I. P. Jones. Computer simulation of the flows of hot gases from the fire at king's cross underground station. In *Institution of Mechanical Engineers (IMEchE) King's Cross Underground Fire: Fire Dynamics and the Organization of Safety*, pages 19–25, London, England, 1989.
- [3] K. Moodie and S. F. Jagger. The technical investigation of the fire at london's king's cross underground station. *J. of Fire Prot. Engr.*, 3:49–63, 1991.
- [4] William D. Davis, Glenn P. Forney, and John H. Klote. Field modeling of room fires. NISTIR 4673, National Institute of Standards and Technology, 1991.
- [5] John H. Klote. Design manual for smoke control systems. Technical Report 4551, National Institute of Standards and Technology, 1991.
- [6] American Society of Civil Engineers, New York. *Minimum Design Loads for Buildings and Other Structures*, July 1990. ASCE 7-88.

A Field Model Input File for Case A - A Two Dimensional Simulation of the Trainer Under Windy Conditions Without Fences or Fans

```
>>FLOW3D
  >>SET LIMITS
    #CALC
      NI=87;
      NJ=32;
      NK=3;
    #ENDCALC
  NUMBER OF I POINTS #NI
  NUMBER OF J POINTS #NJ
  NUMBER OF K POINTS #NK
  END
>>OPTIONS
  CARTESIAN COORDINATES
  RECTANGULAR GRID
  TRANSIENT FLOW
  TEMPERATURE CALCULATION
  COMPRESSIBLE FLOW
  TURBULENT FLOW
  END
>>MODEL DATA
  >>GAS CONSTANTS
    TREF 297.
  >>PHYSICAL PROPERTIES
    >>STANDARD FLUID
      AIR
      REFERENCE TEMPERATURE 24.
      BUOYANCY REFERENCE DENSITY 1.19
      GRAVITY VECTOR 0. -9.8 0.
    END
    >>PHYSICAL CONSTANTS
      DEFAULT SOLID CONDUCTIVITY .0259
    END
  >>SET OPTIONS
    BUOYANCY
    TIME STEPS 100*.10
```

```

        NSTEP 100
/*    INITIAL TIME 100.00 */
    END
/*    >>SET INITIAL GUESS
    RESTORE VARIABLES
    LAST DUMP FILE
    END */

    >>DIFFERENCING SCHEME
        ALL EQUATIONS 'UPWIND'
    END

>>SOLVER DATA
    >>PROGRAM CONTROL
        MAXIMUM NUMBER OF ITERATIONS 30
        OUTPUT MONITOR POINT 40 10 2
        MASS SOURCE TOLERANCE 1.E-6
    END

    >>NUMBER OF SWEEPS
        >>MAXIMA
            U 10
            V 10
            K 20
            EPSILON 20
            P 50
        END
        >>MINIMA
            U 5
            V 5
            P 35
            K 10
            EPSILON 10
        END

    >>UNDER RELAXATION FACTORS
        U .6
        V .6
        P .6
        TE .6
        ED .6
        T .6

```

```

H .6
/* FULL RESIDUAL PRINTING */
END

>>REDUCTION FACTORS
U .1
V .1
P .01
TE .1
ED .01
T .1
H .1
END

>>CREATE GRID
/* >>REGION
  READ GRID FROM DUMPFIL * /
>>SIMPLE GRID
X START 0.
Y START 0.
Z START 0.
  DX 21 * .61 44*.305 20*.61
  DY 2*.61 8*.305 20*.605
  DZ 1*17.06
END
>>MODEL TOPOLOGY
  >>INLETS
    INLET LOCATIONS ( 1, 2,2) = 1
    U VELOCITY ( 1, 2,2) = 5.39
    T 297.
    END
  >>INLETS
    INLET LOCATIONS ( 1, 3,2) = 1
    U VELOCITY ( 1, 3,2) = 6.28
    T 297.
    END
  >>INLETS
    INLET LOCATIONS ( 1, 4,2) = 1
    U VELOCITY ( 1, 4,2) = 6.65
    T 297.
    END
  >>INLETS

```

```

    INLET LOCATIONS      ( 1, 5,2) = 1
    U VELOCITY           ( 1, 5,2) = 6.83
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 6,2) = 1
    U VELOCITY           ( 1, 6,2) = 7.00
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 7,2) = 1
    U VELOCITY           ( 1, 7,2) = 7.14
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 8,2) = 1
    U VELOCITY           ( 1, 8,2) = 7.27
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 9,2) = 1
    U VELOCITY           ( 1, 9,2) = 7.38
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 10,2) = 1
    U VELOCITY           ( 1, 10,2) = 7.49
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 11,2) = 1
    U VELOCITY           ( 1, 11,2) = 7.58
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 12,2) = 1
    U VELOCITY           ( 1, 12,2) = 7.71
    T 297.
    END
>>INLETS
    INLET LOCATIONS      ( 1, 13,2) = 1
    U VELOCITY           ( 1, 13,2) = 7.87

```

```

T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 14,2) = 1
  U VELOCITY         ( 1, 14,2) = 8.00
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 15,2) = 1
  U VELOCITY         ( 1, 15,2) = 8.13
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 16,2) = 1
  U VELOCITY         ( 1, 16,2) = 8.25
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 17,2) = 1
  U VELOCITY         ( 1, 17,2) = 8.35
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 18,2) = 1
  U VELOCITY         ( 1, 18,2) = 8.45
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 19,2) = 1
  U VELOCITY         ( 1, 19,2) = 8.54
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 20,2) = 1
  U VELOCITY         ( 1, 20,2) = 8.63
T 297.
END
>>INLETS
  INLET LOCATIONS    ( 1, 21,2) = 1
  U VELOCITY         ( 1, 21,2) = 8.71
T 297.
END

```

```

>>INLETS
  INLET LOCATIONS ( 1, 22,2) = 1
  U VELOCITY      ( 1, 22,2) = 8.78
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 23,2) = 1
  U VELOCITY      ( 1, 23,2) = 8.86
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 24,2) = 1
  U VELOCITY      ( 1, 24,2) = 8.92
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 25,2) = 1
  U VELOCITY      ( 1, 25,2) = 8.99
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 26,2) = 1
  U VELOCITY      ( 1, 26,2) = 9.05
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 27,2) = 1
  U VELOCITY      ( 1, 27,2) = 9.11
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 28,2) = 1
  U VELOCITY      ( 1, 28,2) = 9.17
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 29,2) = 1
  U VELOCITY      ( 1, 29,2) = 9.23
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 30,2) = 1

```

```

U VELOCITY      ( 1, 30,2) = 9.28
T 297.
END
>>INLETS
INLET LOCATIONS ( 1, 31,2) = 1
U VELOCITY      ( 1, 31,2) = 9.33
T 297.
END
>>PRESSURE OUTFLOW BOUNDARIES
PRESSURE LOCATIONS(#NI,1 TO #NJ,2) =1
PRESSURE (#NI,1 TO #NJ,2) =0.
END
>>PRESSURE OUTFLOW BOUNDARIES
PRESSURE LOCATIONS(#NI,1 TO #NJ,2) =1
PRESSURE (#NI,1 TO #NJ,2) =0.
END
>>SOLID REGION
>>NON CONDUCTING REGION
SOLID CONTROL VOLUMES (19 TO 29,7,2)= 0
SOLID CONTROL VOLUMES (66 TO 73,7,2)= 0
SOLID CONTROL VOLUMES (19,3,2)= 0
SOLID CONTROL VOLUMES (19,6,2)= 0
SOLID CONTROL VOLUMES (73,3,2)= 0
SOLID CONTROL VOLUMES (73,6,2)= 0
/* SOLID DENSITY 8.81E3
SPECIFIC HEAT 1.25E3 */
END

>>STOP

```

B Listing for USRSRC, the Subroutine Used to Model the Propane Burners

```
SUBROUTINE USRSRC(IEQN,ICALL,
+               U,V,W,P,TE,ED,T,H,SCAL,DEN,VIS,
+               XC,YC,ZC,VOL,AREA,VPOR,ARPOR,GDIFF,WFACT,
+               CONV,DIFF,AM,SP,SU,
+               ILIST,RLIST,WORK,IWRFRE,IWORK,IWIFRE)
C
C*****
C
C THIS SUBROUTINE CAN BE USED TO INCLUDE ADDITIONAL SOURCE TERMS IN
C ANY EQUATION
C
C*****
C
C THIS SUBROUTINE IS CALLED BY THE FOLLOWING SUBROUTINES
C   FLOW3D  SCED  SCH  SCMOM  SCPCE  SCSCAL  SCT  SCTE
C
C*****
C
C CALLED ONCE INITIALLY WITH IEQN=0 AND ICALL=0 TO ALLOW USER TO PRE-
C ALLOCATE SPACE IN THE REAL AND INTEGER WORKSPACE STACKS WORK(NRWS)
C AND IWORK(NIWS). THE FIRST FREE LOCATIONS ARE WORK(IWRFRE) AND
C IWORK(IWIFRE).
C
C CALLED SUBSEQUENTLY TWICE PER EQUATION:-
C   1) TO ADD TO THE SOURCE TERMS (ICALL=1)
C   2) TO OVERWRITE THE SOURCE TERMS (ICALL=2)
C
C EACH EQUATION IS LABELLED BY IEQN:
C   1 : U-EQUATION           5 : K-EQUATION
C   2 : V-EQUATION           6 : EPSILON-EQUATION
C   3 : W-EQUATION           7 : T-EQUATION
C   4 : P-EQUATION           8 : H-EQUATION
C                               9+M: M'TH SCALAR EQUATION
C
C WARNING:
C   AM(NIJK,6) IS THE SAME ARRAY FOR THE U-, V- AND W-EQUATIONS.
C   IF IT IS OVERWRITTEN FOR ONE OF THESE EQUATIONS, THE
C   MODIFICATION WILL APPLY TO ALL THREE EQUATIONS.
C
```

```

C*****
C  MODIFIED
C    20/05/87  ADB  PASS ENTIRE WORK SPACE STACKS IN ARGUMENT LIST AND
C                REMOVE XP, YP, ZP FROM ARGUMENT LIST
C    27/05/87  ADB  PASS POROUS INFORMATION IN ARGUMENT LIST
C    29/05/87  ADB  PASS ENTHALPY IN ARGUMENT LIST AND REPLACE
C                SEPARATE LISTS BY ILIST, RLIST
C    23/05/88  DJW  NWRITE NOT DEFINED - INSERTED COMMON /DEVICE/,
C                TIDIED-UP MODIFICATION LIST
C    26/04/89  DJW  TO CORRECT SETTING OF NREQI
C
C*****
C
C    LOGICAL LTURB,LTEMP,LBUOY,LCOMP,LSCAL
C    +      ,LRECT,LCYN,LAXIS,LGRID,LTRANS
C
C    COMMON /ALL/
C    + NI,NIM1,NJ,NJM1,NK,NKM1,NIJ,NIJK
C    COMMON /ADDIMS/
C    + NIP1,NJP1,NKP1,NINDEX,NIGRID,NJGRID,NKGRID,NDGRID,NVAR,NPROP
C    +,NDVAR,NDPROP,NDXNN,NDGEOM,NDCOEF,NILIST,NRLIST,NIWS,NRWS
C    +,NITURB,NJTURB,NKTURB,NDTURB,NITEMP,NJTEMP,NKTEMP,NDTEMP
C    +,NISCAL,NJSCAL,NKSCAL,NDSCAL,NITRAN,NJTRAN,NKTRAN,NDTRAN
C    COMMON /BOUY/
C    + GBETX,GBETY,GBETZ
C    COMMON /DEVICE/
C    + NREAD,NWRITE,NRDISK,NWDISK
C    COMMON /LISTS/
C    + JTDIR,LIDIR,JRDIR,LRDIR,JTNEUM,LINEUM,JTNEUP,LINEUP,JRNEUP,LRNEUP
C    +,JTSYS,LISYS,JTPS,LIPS,JTOS,LIOS,JRLOS,LROS
C    +,JTPOS,LIPOS,JRLPOS,LRPOS,JTPOT,LIPOT,JRLPOT,LRPOT
C    +,JTWS,LIWS,JRLWS,LRWS,JTBS,LIBS,JRLBS,LRBS
C    COMMON /FLUPR/
C    + VISCOS,DENSIT
C    COMMON /LOGIC/
C    + LTURB,LTEMP,LBUOY,LCOMP,LSCAL
C    +,LRECT,LCYN,LAXIS,LGRID,LTRANS
C    COMMON /SCALAR/
C    + NSCAL
C    COMMON /SPARM/
C    + SMALL,SORMAX,NITER,INDPRI,MAXIT,IPREF,JPREF,KPREF,IMON,JMON,KMON
C    COMMON /TEMP/

```

```

+ TDIFF,CPRES,FLOG,TYPLUS
COMMON /TRANSR/
+ TIME,DT,DTINVF,TPARM
COMMON /TURB/
+ CMU,C1,C2,C3,CAPPA,ELOG,PRED,PRTE,CMU14,CMU34,XYPLUS
C
DIMENSION
+ U(NI,NJ,NK),V(NI,NJ,NK),W(NI,NJ,NK),P(NI,NJ,NK)
+,TE(NITURB,NJTURB,NKTURB),ED(NITURB,NJTURB,NKTURB)
+,T(NITEMP,NJTEMP,NKTEMP),H(NITEMP,NJTEMP,NKTEMP)
+,SCAL(NISCAL,NJSCAL,NKSCAL,NSCAL)
+,DEN(NI,NJ,NK),VIS(NI,NJ,NK)
DIMENSION
+ XC(NIP1,NJP1,NKP1),YC(NIP1,NJP1,NKP1),ZC(NIP1,NJP1,NKP1)
+,VOL(NI,NJ,NK),AREA(NI,NJ,NK,3,NINDEX)
+,VPOR(NI,NJ,NK),ARPOR(NI,NJ,NK,3,NINDEX)
+,GDIFF(NI,NJ,NK,3,NINDEX),WFACT(NI,NJ,NK,3)
+,CONV(NI,NJ,NK,3),DIFF(NI,NJ,NK,3,NINDEX)
+,AM(NI,NJ,NK,6),SP(NI,NJ,NK),SU(NI,NJ,NK)
DIMENSION ILIST(NILIST),RLIST(NRLIST),WORK(NRWS),IWORK(NIWS)
C
C*****
C
C-----EXAMPLE: SET POINTERS TO AND RESERVE USER WORKSPACE
C
C IPRUSR = POINTER TO USER'S CHUNK OF REAL WORK SPACE.
C IPIUSR = POINTER TO USER'S CHUNK OF INTEGER WORK SPACE.
C NWRUSR = SIZE OF USER'S CHUNK OF REAL WORK SPACE.
C NWIUSR = SIZE OF USER'S CHUNK OF INTEGER WORK SPACE.
C
C SAVE IPRUSR, IPIUSR
C
C IF (ICALL .EQ. 0) THEN
C
C NWRUSR = 0
C NWIUSR = 0
C IPRUSR = IWRFRE
C IPIUSR = IWIFRE
C
C NREQR = IWRFRE + NWRUSR - 1
C IF (NREQR.GT.NRWS) GO TO 991
C NREQI = IWIFRE + NWIUSR - 1

```

```

        IF (NREQI.GT.NIWS) GO TO 992
C
        IWRFRE = IWRFRE + NWRUSR
        IWIFRE = IWIFRE + NWIUSR
C
        ENDIF
C
C-----USER MODIFICATIONS TO SOURCE TERMS:
C
        IF(IEQN.EQ.8.AND.ICALL.EQ.1) THEN
        SPWR = 125.E6/64.
        DO 25 I = 32, 63
            SU(I,6,2)=SU(I,6,2)+SPWR
            SU(I,7,2)=SU(I,7,2)+SPWR
        25 CONTINUE
        END IF
C
        RETURN
C
C-----ERROR TRAPPING.
C
991  CONTINUE
        WRITE(NWRITE,691) NREQR,NRWS
691  FORMAT(//,' **** ERROR ABORT IN SUBROUTINE USRSRC ****',/,
+         ' INSUFFICIENT REAL WORK SPACE',/,
+         ' REQUIRED = ',I10,' AVAILABLE = ',I10)
        STOP
C
992  CONTINUE
        WRITE(NWRITE,692) NREQI,NIWS
692  FORMAT(//,' **** ERROR ABORT IN SUBROUTINE USRSRC ****',/,
+         ' INSUFFICIENT INTEGER WORK SPACE',/,
+         ' REQUIRED = ',I10,' AVAILABLE = ',I10)
        STOP
        END

```

C Listing of the File Used by OUTPROC to Produce Vector Plots

```
>> OUTPROC
  >> SET LIMITS
  /*-----*/
  /* FOR 2D PLOTS SET : */
  /* SPACE DIMENSIONS = 2 */
  /* NO. OF ELEMENTS = MAX(NI*NJ,NJ*NK,NK*NI) */
  /* NO. OF NODES = MAX(NIP1*NJP1,NJP1*NKP1,NKP1*NIP1) */
  /* NO. OF FREEDOMS = VARIABLES * NODES */
  /*-----*/
    SPACE DIMENSIONS      2
    VARIABLES              7
    ELEMENTS              3000
    NODES                  3000
    FREEDOMS              21000
  END

  >> SET OPTIONS
    TWO DIMENSIONS
  END

  >> SET VARIABLES
    VARIABLE NAMES 'U' 'V' 'W' 'P' 'TE' 'ED' 'T'
  END

  >> MODEL DATA
    >> CREATE GRID
      >> GENERATE A USER GRID
        MASS CONTROL VOLUME VERTICES
        SOLID SIDE INTERPOLATION /* SET VARIABLES TO 0 AT WALLS */
        READ FROM STREAM 21 /* READ DUMPFIL FROM STREAM 21 */
        SLICE COORDINATE 3 /* IE K PLANES */
        PLANE NUMBER 2 /* IE K= 6 */
      END

  >> LOAD USER VALUES
    >> OUTPUT DATA
      /* >> SELECT TIME
        TIME 9.
      END */
```

```
>> SET PLOT OPTIONS
    HEADING 'NAVY TRAINER'
    USE LOCAL EXTREMA
/* EXAMPLE OF ZOOMING IN ON A REGION
X LIMITS OF ZOOM  1.0 2.0
Y LIMITS OF ZOOM  0.5 0.75
    COMMENTED OUT HERE          */

>> SET OUTPUT POINTS
    >> SELECT ALL NODES

>> PLOT VECTORS
    HEADING 'NAVY TRAINER'
    ARROW SCALE 10.0
    CAPTION 'VELOCITY VECTORS'
    VARIABLES 'U' 'V'
/* PLOT REFERENCE VECTOR */
    AUTOMATIC SCALING
    COLOUR USING VARIABLE 'T'
    NUMBER OF INTERVALS 7
    INTERVALS 300. 350. 400. 450. 500. 550. 600.
    COLOURS 'BLUE' 'CYAN' 'GREEN' 'YELLOW' 'ORANGE' 'PINK' 'RED'
    END

>> STOP
>> END OF DATA
```

D Listing of the File Used by OUTPROC to Produce Contour Plots

```
>> OUTPROC
  >> SET LIMITS
    /*-----*/
    /* FOR 2D PLOTS SET : */
    /* SPACE DIMENSIONS = 2 */
    /* NO. OF ELEMENTS = MAX(NI*NJ,NJ*NK,NK*NI) */
    /* NO. OF NODES = MAX(NIP1*NJP1,NJP1*NKP1,NKP1*NIP1) */
    /* NO. OF FREEDOMS = VARIABLES * NODES */
    /*-----*/
    SPACE DIMENSIONS      2
    VARIABLES             7
    ELEMENTS              3300
    NODES                 3300
    FREEDOMS              25000
    END

  >> SET OPTIONS
    TWO DIMENSIONS
    END

  >> SET VARIABLES
    VARIABLE NAMES 'U' 'V' 'W' 'P' 'TE' 'ED' 'T'
    END

  >> MODEL DATA
    >> CREATE GRID
      >> GENERATE A USER GRID
        MASS CONTROL VOLUME VERTICES
        FLUID SIDE INTERPOLATION
        /* SOLID SIDE INTERPOLATION SET VARIABLES TO 0 AT WALLS */
        READ FROM STREAM 21 /* READ DUMPFIL FROM STREAM 21 */
        SLICE COORDINATE 3 /* IE K PLANES */
        PLANE NUMBER 2 /* IE K= 6 */
        END

  >> LOAD USER VALUES
    >> OUTPUT DATA
      /* >> SELECT TIME
        TIME 9.
```

```
END */

>> SET PLOT OPTIONS
    HEADING 'NAVY TRAINER'
    USE LOCAL EXTREMA
/* EXAMPLE OF ZOOMING IN ON A REGION
X LIMITS OF ZOOM 1.0 2.0
Y LIMITS OF ZOOM 0.5 0.75
COMMENTED OUT HERE          */

>> SET OUTPUT POINTS
>> SELECT ALL NODES

>> PLOT CONTOURS
    HEADING 'NAVY TRAINER'
    CAPTION 'T TEMPERATURE CONTOURS'
    NUMBER OF CONTOURS 7
    CONTOUR VALUES 400. 450. 500. 550. 600. 650. 700.
    VARIABLE 'T'
    COLOURS 'BLUE' 'CYAN' 'GREEN' 'YELLOW' 'ORANGE' 'PINK' 'RED'
    END

>> STOP
>> END OF DATA
```

E Field Model Input File for Case G - A Three Dimensional Simulation of the Trainer Under Windy Conditions with a Fence

```
>>FLOW3D
  >>SET LIMITS
    #CALC
      NI=45;
      NJ=32;
      NK=38;
    #ENDCALC
  NUMBER OF I POINTS #NI
  NUMBER OF J POINTS #NJ
  NUMBER OF K POINTS #NK
  NUMBER OF DIMENSIONS 3
  TOTAL INTEGER WORK SPACE 200000
  TOTAL REAL WORK SPACE 1700000
  TOTAL INTEGER LIST SPACE 20000
  TOTAL REAL LIST SPACE 400000
  END
>>OPTIONS
  CARTESIAN COORDINATES
  RECTANGULAR GRID
  TRANSIENT FLOW
  TEMPERATURE CALCULATION
  COMPRESSIBLE FLOW
  TURBULENT FLOW
  /* POROUS FLOW */
  END
>>MODEL DATA
  >>GAS CONSTANTS
    TREF 297.
  >>PHYSICAL PROPERTIES
    >>STANDARD FLUID
      AIR
      REFERENCE TEMPERATURE 24.
      BUOYANCY REFERENCE DENSITY 1.19
      GRAVITY VECTOR 0. -9.8 0.
    END
  >>PHYSICAL CONSTANTS
    DEFAULT SOLID CONDUCTIVITY .0259
```

```

END
>>SET OPTIONS
  BUOYANCY
  TIME STEPS 40 *.25
  NSTEP 20
/*  INITIAL TIME 100.00 */
  END
/*  >>SET INITIAL GUESS
  RESTORE VARIABLES
  LAST DUMP FILE
  END */

>>DIFFERENCING SCHEME
  ALL EQUATIONS 'UPWIND'
  END

>>SOLVER DATA
  >>PROGRAM CONTROL
    MAXIMUM NUMBER OF ITERATIONS 30
    OUTPUT MONITOR POINT 40 10 2
    MASS SOURCE TOLERANCE 1.E-6
  END

  >>NUMBER OF SWEEPS
    >>MAXIMA
      U 10
      V 10
      W 10
      K 20
      EPSILON 20
      P 50
      END
    >>MINIMA
      U 5
      V 5
      W 5
      P 35
      K 10
      EPSILON 10
      END

  >>UNDER RELAXATION FACTORS

```

```

U .6
V .6
W .6
P .6
TE .6
ED .6
T .6
H .6
/* FULL RESIDUAL PRINTING */
END

>>REDUCTION FACTORS
  U .1
  V .1
  W .1
  P .01
  TE .1
  ED .01
  T .1
  H .1
END

>>CREATE GRID
/* >>REGION
  READ GRID FROM DUMPFIL *
>>SIMPLE GRID
X START 0.
Y START 0.
Z START 0.
  DX 43 * 1.22
  DY 2*.61  8*.305  20*.605
  DZ 36 * 1.22
END

>>MODEL TOPOLOGY
  >>INLETS
    INLET LOCATIONS ( 1, 2,2 TO #NK) = 1
    U VELOCITY      ( 1, 2,2 TO #NK) = 3.81
    W VELOCITY      ( 1, 2,2 TO #NK) = 3.81
    T 297.
  END
  >>INLETS
    INLET LOCATIONS ( 1, 3,2 TO #NK) = 1

```

```

U VELOCITY      ( 1, 3,2 TO #NK) = 4.44
W VELOCITY      ( 1, 3,2 TO #NK) = 4.44
T 297.
END
>>INLETS
  INLET LOCATIONS ( 1, 4,2 TO #NK) = 1
  U VELOCITY      ( 1, 4,2 TO #NK) = 4.7
  W VELOCITY      ( 1, 4,2 TO #NK) = 4.7
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 5,2 TO #NK) = 1
  U VELOCITY      ( 1, 5,2 TO #NK) = 4.82
  W VELOCITY      ( 1, 5,2 TO #NK) = 4.82
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 6,2 TO #NK) = 1
  U VELOCITY      ( 1, 6,2 TO #NK) = 4.95
  W VELOCITY      ( 1, 6,2 TO #NK) = 4.95
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 7,2 TO #NK) = 1
  U VELOCITY      ( 1, 7,2 TO #NK) = 5.05
  W VELOCITY      ( 1, 7,2 TO #NK) = 5.05
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 8,2 TO #NK) = 1
  U VELOCITY      ( 1, 8,2 TO #NK) = 5.14
  W VELOCITY      ( 1, 8,2 TO #NK) = 5.14
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 9,2 TO #NK) = 1
  U VELOCITY      ( 1, 9,2 TO #NK) = 5.22
  W VELOCITY      ( 1, 9,2 TO #NK) = 5.22
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 10,2 TO #NK) = 1

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U VELOCITY          ( 1, 10,2 TO #NK) = 5.3
W VELOCITY          ( 1, 10,2 TO #NK) = 5.3
T 297.
END
>>INLETS
  INLET LOCATIONS   ( 1, 11,2 TO #NK) = 1
  U VELOCITY        ( 1, 11,2 TO #NK) = 5.36
  W VELOCITY        ( 1, 11,2 TO #NK) = 5.36
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1, 12,2 TO #NK) = 1
  U VELOCITY        ( 1, 12,2 TO #NK) = 5.45
  W VELOCITY        ( 1, 12,2 TO #NK) = 5.45
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1, 13,2 TO #NK) = 1
  U VELOCITY        ( 1, 13,2 TO #NK) = 5.56
  W VELOCITY        ( 1, 13,2 TO #NK) = 5.56
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1, 14,2 TO #NK) = 1
  U VELOCITY        ( 1, 14,2 TO #NK) = 5.66
  W VELOCITY        ( 1, 14,2 TO #NK) = 5.66
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1, 15,2 TO #NK) = 1
  U VELOCITY        ( 1, 15,2 TO #NK) = 5.75
  W VELOCITY        ( 1, 15,2 TO #NK) = 5.75
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1, 16,2 TO #NK) = 1
  U VELOCITY        ( 1, 16,2 TO #NK) = 5.83
  W VELOCITY        ( 1, 16,2 TO #NK) = 5.83
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1, 17,2 TO #NK) = 1

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U VELOCITY      ( 1, 17,2 TO #NK) = 5.90
W VELOCITY      ( 1, 17,2 TO #NK) = 5.90
T 297.
END
>>INLETS
  INLET LOCATIONS ( 1, 18,2 TO #NK) = 1
  U VELOCITY      ( 1, 18,2 TO #NK) = 5.98
  W VELOCITY      ( 1, 18,2 TO #NK) = 5.98
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 19,2 TO #NK) = 1
  U VELOCITY      ( 1, 19,2 TO #NK) = 6.04
  W VELOCITY      ( 1, 19,2 TO #NK) = 6.04
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 20,2 TO #NK) = 1
  U VELOCITY      ( 1, 20,2 TO #NK) = 6.10
  W VELOCITY      ( 1, 20,2 TO #NK) = 6.10
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 21,2 TO #NK) = 1
  U VELOCITY      ( 1, 21,2 TO #NK) = 6.16
  W VELOCITY      ( 1, 21,2 TO #NK) = 6.16
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 22,2 TO #NK) = 1
  U VELOCITY      ( 1, 22,2 TO #NK) = 6.21
  W VELOCITY      ( 1, 22,2 TO #NK) = 6.21
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 23,2 TO #NK) = 1
  U VELOCITY      ( 1, 23,2 TO #NK) = 6.26
  W VELOCITY      ( 1, 23,2 TO #NK) = 6.26
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 24,2 TO #NK) = 1

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U VELOCITY      ( 1, 24,2 TO #NK) = 6.31
W VELOCITY      ( 1, 24,2 TO #NK) = 6.31
T 297.
END
>>INLETS
  INLET LOCATIONS ( 1, 25,2 TO #NK) = 1
  U VELOCITY      ( 1, 25,2 TO #NK) = 6.36
  W VELOCITY      ( 1, 25,2 TO #NK) = 6.36
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 26,2 TO #NK) = 1
  U VELOCITY      ( 1, 26,2 TO #NK) = 6.4
  W VELOCITY      ( 1, 26,2 TO #NK) = 6.4
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 27,2 TO #NK) = 1
  U VELOCITY      ( 1, 27,2 TO #NK) = 6.44
  W VELOCITY      ( 1, 27,2 TO #NK) = 6.44
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 28,2 TO #NK) = 1
  U VELOCITY      ( 1, 28,2 TO #NK) = 6.48
  W VELOCITY      ( 1, 28,2 TO #NK) = 6.48
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 29,2 TO #NK) = 1
  U VELOCITY      ( 1, 29,2 TO #NK) = 6.53
  W VELOCITY      ( 1, 29,2 TO #NK) = 6.53
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 30,2 TO #NK) = 1
  U VELOCITY      ( 1, 30,2 TO #NK) = 6.56
  W VELOCITY      ( 1, 30,2 TO #NK) = 6.56
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1, 31,2 TO #NK) = 1

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U VELOCITY      ( 1, 31,2 TO #NK) = 6.6
W VELOCITY      ( 1, 31,2 TO #NK) = 6.6
T 297.
END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 2, 1) = 1
  U VELOCITY      ( 1 TO #NI, 2, 1) = 3.81
  W VELOCITY      ( 1 TO #NI, 2, 1) = 3.81
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 3,1) = 1
  U VELOCITY      ( 1 TO #NI, 3,1) = 4.44
  W VELOCITY      ( 1 TO #NI, 3,1) = 4.44
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 4,1) = 1
  U VELOCITY      ( 1 TO #NI, 4,1) = 4.7
  W VELOCITY      ( 1 TO #NI, 4,1) = 4.7
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 5,1) = 1
  U VELOCITY      ( 1 TO #NI, 5,1) = 4.82
  W VELOCITY      ( 1 TO #NI, 5,1) = 4.82
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 6,1) = 1
  U VELOCITY      ( 1 TO #NI, 6,1) = 4.95
  W VELOCITY      ( 1 TO #NI, 6,1) = 4.95
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 7,1) = 1
  U VELOCITY      ( 1 TO #NI, 7,1) = 5.05
  W VELOCITY      ( 1 TO #NI, 7,1) = 5.05
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 8,1) = 1

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U VELOCITY          ( 1 TO #NI, 8,1) = 5.14
W VELOCITY          ( 1 TO #NI, 8,1) = 5.14
T 297.
END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 9,1) = 1
  U VELOCITY        ( 1 TO #NI, 9,1) = 5.22
  W VELOCITY        ( 1 TO #NI, 9,1) = 5.22
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 10,1) = 1
  U VELOCITY        ( 1 TO #NI, 10,1) = 5.3
  W VELOCITY        ( 1 TO #NI, 10,1) = 5.3
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 11,1) = 1
  U VELOCITY        ( 1 TO #NI, 11,1) = 5.36
  W VELOCITY        ( 1 TO #NI, 11,1) = 5.36
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 12,1) = 1
  U VELOCITY        ( 1 TO #NI, 12,1) = 5.45
  W VELOCITY        ( 1 TO #NI, 12,1) = 5.45
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 13,1) = 1
  U VELOCITY        ( 1 TO #NI, 13,1) = 5.56
  W VELOCITY        ( 1 TO #NI, 13,1) = 5.56
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 14,1) = 1
  U VELOCITY        ( 1 TO #NI, 14,1) = 5.66
  W VELOCITY        ( 1 TO #NI, 14,1) = 5.66
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 15,1) = 1

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U VELOCITY      ( 1 TO #NI, 15,1) = 5.75
W VELOCITY      ( 1 TO #NI, 15,1) = 5.75
T 297.
END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 16,1) = 1
  U VELOCITY      ( 1 TO #NI, 16,1) = 5.83
  W VELOCITY      ( 1 TO #NI, 16,1) = 5.83
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 17,1) = 1
  U VELOCITY      ( 1 TO #NI, 17,1) = 5.90
  W VELOCITY      ( 1 TO #NI, 17,1) = 5.90
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 18,1) = 1
  U VELOCITY      ( 1 TO #NI, 18,1) = 5.98
  W VELOCITY      ( 1 TO #NI, 18,1) = 5.98
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 19,1) = 1
  U VELOCITY      ( 1 TO #NI, 19,1) = 6.04
  W VELOCITY      ( 1 TO #NI, 19,1) = 6.04
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 20,1) = 1
  U VELOCITY      ( 1 TO #NI, 20,1) = 6.10
  W VELOCITY      ( 1 TO #NI, 20,1) = 6.10
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 21,1) = 1
  U VELOCITY      ( 1 TO #NI, 21,1) = 6.16
  W VELOCITY      ( 1 TO #NI, 21,1) = 6.16
  T 297.
  END
>>INLETS
  INLET LOCATIONS ( 1 TO #NI, 22,1) = 1

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U VELOCITY          ( 1 TO #NI, 22,1) = 6.21
W VELOCITY          ( 1 TO #NI, 22,1) = 6.21
T 297.
END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 23,1) = 1
  U VELOCITY        ( 1 TO #NI, 23,1) = 6.26
  W VELOCITY        ( 1 TO #NI, 23,1) = 6.26
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 24,1) = 1
  U VELOCITY        ( 1 TO #NI, 24,1) = 6.31
  W VELOCITY        ( 1 TO #NI, 24,1) = 6.31
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 25,1) = 1
  U VELOCITY        ( 1 TO #NI, 25,1) = 6.36
  W VELOCITY        ( 1 TO #NI, 25,1) = 6.36
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 26,1) = 1
  U VELOCITY        ( 1 TO #NI, 26,1) = 6.4
  W VELOCITY        ( 1 TO #NI, 26,1) = 6.4
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 27,1) = 1
  U VELOCITY        ( 1 TO #NI, 27,1) = 6.44
  W VELOCITY        ( 1 TO #NI, 27,1) = 6.44
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 28,1) = 1
  U VELOCITY        ( 1 TO #NI, 28,1) = 6.48
  W VELOCITY        ( 1 TO #NI, 28,1) = 6.48
  T 297.
  END
>>INLETS
  INLET LOCATIONS   ( 1 TO #NI, 29,1) = 1

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```

U VELOCITY      ( 1 TO #NI, 29,1) = 6.53
W VELOCITY      ( 1 TO #NI, 29,1) = 6.53
T 297.
END
>>INLETS
INLET LOCATIONS ( 1 TO #NI, 30,1) = 1
U VELOCITY      ( 1 TO #NI, 30,1) = 6.56
W VELOCITY      ( 1 TO #NI, 30,1) = 6.56
T 297.
END
>>INLETS
INLET LOCATIONS ( 1 TO #NI, 31,1) = 1
U VELOCITY      ( 1 TO #NI, 31,1) = 6.6
W VELOCITY      ( 1 TO #NI, 31,1) = 6.6
T 297.
END
>>PRESSURE OUTFLOW BOUNDARIES
PRESSURE LOCATIONS(#NI,1 TO #NJ,1 TO #NK) =1
PRESSURE (#NI,1 TO #NJ,1 TO #NK) =0.
PRESSURE LOCATIONS(1 TO #NI,1 TO #NJ,#NK) =1
PRESSURE (1 TO #NI,1 TO #NJ,#NK) =0.
PRESSURE LOCATIONS(1 TO #NI,#NJ,1 TO #NK) =1
PRESSURE (1 TO #NI,#NJ,1 TO #NK) =0.
END
>>SOLID REGION
>>NON CONDUCTING REGION
SOLID CONTROL VOLUMES (12 TO 19,8,15 TO 31)= 0
SOLID CONTROL VOLUMES (33 TO 39,8,15 TO 31)= 0
SOLID CONTROL VOLUMES (20 TO 32,8,15 TO 18)= 0
SOLID CONTROL VOLUMES (20 TO 32,8,28 TO 31)= 0
SOLID CONTROL VOLUMES (12,7,15 TO 31)=0
SOLID CONTROL VOLUMES (12,4,15 TO 31)=0
SOLID CONTROL VOLUMES (13 TO 39,7,15)=0
SOLID CONTROL VOLUMES (13 TO 39,4,15)=0
SOLID CONTROL VOLUMES (13 TO 39,7,31)=0
SOLID CONTROL VOLUMES (13 TO 39,4,31)=0
SOLID CONTROL VOLUMES (39,7,16 TO 30)=0
SOLID CONTROL VOLUMES (39,4,16 TO 30)=0
/* SOLID DENSITY 8.81E3
SPECIFIC HEAT 1.25E3 */
END

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The purpose of this report is to document a series of numerical experiments performed to analyze strategies for eliminating flame blow-down occurring in the Navy's 19F4 fire fighting trainer. The first strategy involves the use of a fence in the way fences are used as tennis court wind breaks. The second strategy involves the use of fans to pressurize the space below the propane burners. Numerical simulations were performed for various fence heights, fence distances from the platform and fan volume flow rates. These tests confirmed that flame blow-down occurs when no action is taken to prevent it and predicted that blow-down will be reduced with the use of a fence and a fan.

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